EFFECTS OF INCREASING ΔT ON POWER PLANT ENTRAINMENT MORTALITY

AT INDIAN POINT, NEW YORK

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J.R. Schubel
J.R. Schubel, Director

ABSTRACT

In this report we have analyzed the effect of increasing ΔT, the temperature rise across the condensers, by decreasing Q the cooling water flow rate, on the entrainment mortality rate per unit concentration, R/η, of pump entrained organisms at Indian Point Units 2 and 3. We show that $R/\eta = Qf$ where f is the ratio of the number of organisms killed 24 hours after passage through a condenser tube to the number entrained. Using data collected on the NYU condenser tube simulator by one of us (O'Connor), we estimated f for striped bass post yolk sac larvae as a function of temperature. We then assumed that Indian Point Units 2 and 3 were both operating at 873 MWe at a ΔT of 8.5°C and a Q of 109.77 m^3s^{-1} and calculated R/η over a range of river temperatures (13-27°C) and ΔTs (8.5 - 24.5°C) to see what changes would occur. Unexpectedly, we found that there was little advantage to increasing ΔT (decreasing Q) for river temperatures $\lesssim$ 16°C. This was due to the marked synergism between thermal and physical stresses in the simulator data.

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I. INTRODUCTION

The primary objective of this report was to determine to what extent pump entrainment mortalities could be reduced at Units 2 and 3 of the Consolidated Edison of NY, Inc./Power Authority of the State of NY Indian Point generating facilities on the Hudson River by adjusting the flow rates of cooling water, and as a result, their ΔTs.

In selecting an excess temperature at which to operate a power plant with a once-through cooling system it has been customary to consider only *thermal stresses* and to use the ratio of the number of organisms killed to the number of organisms entrained as an index of environmental damage. This frequently leads to the selection of a low excess temperature, ΔT, which, in turn, requires a large volume flow of cooling water. But mortalities of entrained organisms can also be caused by physical and chemical stresses. The fundamental concept is that the lower the excess temperature, the greater must be the volume rate at which water is taken into the system. As a result, more organisms are entrained and exposed, not only to thermal stress, but to physical and chemical stresses as well. The most appropriate ΔT is the one that minimizes damage to the biota.

The objective is to select a ΔT (and cooling water flow rate) that minimizes the entrainment mortality rate, R, defined as the number of organisms killed per unit time. It should be noted that R is very different from the often used entrainment mortality fraction f which is defined as the ratio of the number of organisms killed to the number entrained in the system. Note particularly that if one wants to reduce the damage to the biota, it is R, not f, that must be minimized.

Let E be the rate at which organisms are entrained by the system. Then

$$R = fE \qquad (1)$$

If η is the density of organisms in the water exposed to the intake and Q the volume rate of intake, then, in terms of Q, the entrainment rate E is

$$E = \eta Q \qquad (2)$$

Substituting (2) into (1) we have

$$R = f\eta Q$$

or

$$R/\eta = fQ \qquad (3)$$

where fQ is now the number of organisms killed per unit time per unit concentration in the receiving waters.

The mortality fraction f has three causes: thermal (t), physical (p), and chemical (c). That is,

$$f = \phi(t,p,c) \qquad (4)$$

Since biocides are not used at the Indian Point plants, chemical stresses need not be considered and (4) becomes

$$f = \Phi(t,p,o) \qquad (5)$$

It turns out, however, that t and p are not independent variables. Recent NYU data (1979) collected by O'Connor in a condenser tube simulator suggests that mortalities of striped bass larvae, passed through condenser tubes at velocities appropriate for the Indian Point units, increased with ΔT over and above that which would have occurred as a result of ΔT alone. This synergism is probably due to the fact that mortalities due to thermal and physical stresses are related through some physiological parameter. While the NYU data do not permit separation of the effects of thermal and physical stresses, they are appropriate for determining f for Indian Point Units 2 and 3 and thus whether or not ichthyoplankton mortalities could be reduced by increasing ΔT (decreasing Q).

II. EVALUATING THE EFFECT OF VARYING ΔT ON THE ENTRAINMENT MORTALITY RATE

A. *Representative Important Species*

The use of Representative Important Species to assess environmental impacts is recommended by the Environmental Protection Agency (EPA, 1973). For identification as a Representative Important Species, a species must meet one or more of the criteria listed below. It must be:

(1) commercially or recreationally valuable
(2) threatened or endangered
(3) critical to structure and function
(4) potentially capable of becoming a localized nuisance species
(5) necessary for the well-being of those species enumerated in 1-4, above
(6) representative of the thermal requirements of important species, but which may themselves not be important.

Those organisms usually considered most sensitive to thermal stresses of pump entrainment are the eggs and larval stages of finfishes and shellfishes (Schubel and Marcy, 1978). Protection of these life history stages should ensure adequate protection of Representative Important Species of phytoplankton and zooplankton.

The Representative Important Species of finfishes and shellfishes in the Hudson River and Hudson River estuary are listed in Table 1.

Table 1

Representative Important Species of finfish for Hudson River near Indian Point[1]

White perch	*Morone americana*
White catfish	*Ictalurus catus*
Alewife	*Alosa pseudoharengus*
Atlantic tomcod	*Microgadus tomcod*
Striped bass	*Morone saxatilis*
Spottail shiner	*Notropis husonius*
Atlantic sturgeon	*Acipenser oxyrhynchus*
Shortnose sturgeon	*Acipenser brevirostrum*
Weakfish	*Cynoscion regalis*
Bay anchovy	*Anchoa mitchilli*
Scud	*Gammarus spp.*

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[1] (EA, 1978) Thermal Effects Literature Review for Hudson River Representative Important Species, March 1978

Of the Representative Important Species listed in Table 1, we have chosen to concentrate on one--striped bass *(Morone saxatilis)*. This is the species generally considered most important in the eyes of the public, and it is the only species for which necessary data on fractional mortalities due to all different kinds of stresses--thermal, chemical, and physical--are available.

In Figure 1 we have plotted the times and temperatures when striped bass eggs, yolk sac larvae, and post yolk sac larvae were found in the Hudson River in 1971 and in 1972 (Lauer *et al.*, 1974). While there are year to year variations, these data indicate:

(1) Striped bass eggs begin to be observed when water temperatures reach 8-10°C, usually about the beginning of May;
(2) Peak abundances of eggs are found when water temperatures reach about 12-15°C which usually occurs in mid to late May;
(3) By mid-June, eggs are no longer collected from the river--they have either hatched or died;
(4) Yolk sac larvae begin to be observed about the same time eggs do, the beginning of May (water temperature 8-10°C). This is expected since the incubation period of striped bass eggs is only about 3 days at these temperatures;
(5) Peak abundances of yolk sac larvae are observed from about the third week in May until early to mid-June--river temperatures of 14-20°C;
(6) Post yolk sac larvae are observed from early May to late July (water temperatures 10-25°C). Peak abundances are usually found from late May to mid-June. In 1972 Lauer *et al.*, 1974 reported

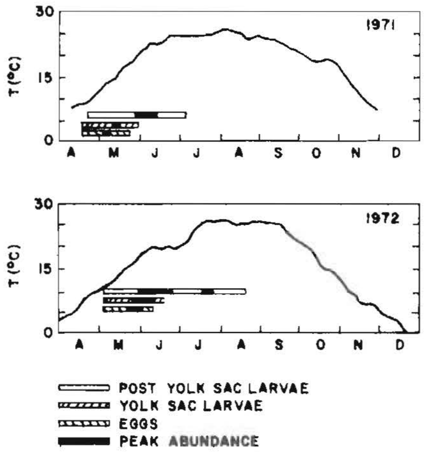

Figure 1. Striped bass eggs and larvae occurrence in the Hudson River off Indian Point as a function of river temperature for the years 1971 and 1972 (after Lauer *et al.*, 1974).

a second peak abundance of post yolk sac larvae in late July.

Other, longer-term river temperature data would be useful in establishing the normal (average) temperature cycle since spawning is triggered primarily by temperature.

B. *Seasonal Variation of River Temperature*

The seasonal variation of near-surface temperature of the Hudson River at Indian Point is shown in Figure 2 for the years 1974-1977. The data are from Consolidated Edison of NY, Inc., 1978. The curves represent average daily temperatures; the ends of the bars correspond to weekly averages of the daily minimum and maximum temperatures. The data show an annual cycle in temperature typical of mid-latitude rivers and coastal waters. Maximum temperatures are observed in July and August reaching approximately 28°C. Minimum temperatures of about -1°C occur in January and February. The rate of change of temperature with respect to time is positive for the months of March to August, is negative for September to December, and is nearly zero for the months of January and February.

Using data from Figures 1 and 2 and from other sources, we can establish some general conclusions about the times of year when striped bass eggs and larvae are found in the Hudson and the range of temperatures characteristic of these periods. These are summarized in Table 2.

C. *Determining f*

NYU's power plant condenser tube simulator is an instrument in which organisms are subjected to velocities, biocides, and temperature and pressure changes that presumably mimic the stresses encountered by organisms entrained in the cooling water flow of a power plant and passed through the condenser (Ginn *et al.*, 1978). It does not, however, simulate the stresses associated with passage through the water boxes or pumps.

Tables 3, 4, and 5 summarize values of f for striped bass post yolk sac larvae acclimated to 16.0, 17.2, 18.0, and 19.0°C and exposed in the NYU simulator to physical stresses and to a variety of excess temperatures ranging from 0.0 to 18.0°C. Flow velocities were 1, 2, or 3 $m\ s^{-1}$ as noted and the period of exposure to excess temperature was 10 minutes. After passing through the condenser simulator, organisms were collected with an LMS larval table and held at the appropriate ΔT for the remainder of the 10 minute exposure period. Mortalities were determined 24 hours after exposure. For each experimental run, 50-100 organisms were used. Controls were exposed to the same time-temperature combinations without passage through the simulator. Larvae acclimated to 16°C generally had lower survivals in the controls and in the experimental subsamples than organisms acclimated to any of the higher excess temperatures, Tables 3, 4, 5. The reason is not clear; it may be due to genetic differences, or to unexplained environmental conditions in the holding baths.[1]

The f values in Tables 3, 4, and 5 were calculated from the relation

$$f = [1-(\%\text{Survivors}/\%\text{Survivors(Control)})] \quad (6)$$

and plotted on Figure 3 as a function of temperature. The data have been fitted with a linear least squares regression; the Standard Error of Estimate of f on T is also shown. The regression equation is

$$f = -0.8052 + 0.0480\ T \quad (7)$$

For our analysis we have assumed that Units 2 and 3 are generating 873 MWe each (net rated capacity for #2; 90% of net rated capacity for #3), at a ΔT of 8.5°C and a cooling water flow Q of 109.77 m^3s^{-1}. Since Q is indirectly proportional to ΔT, we have from equation (3)

$$R/\eta = fQ = f[109.77(\frac{8.5}{\Delta T})] \quad (8)$$

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[1] See appendix for original data.

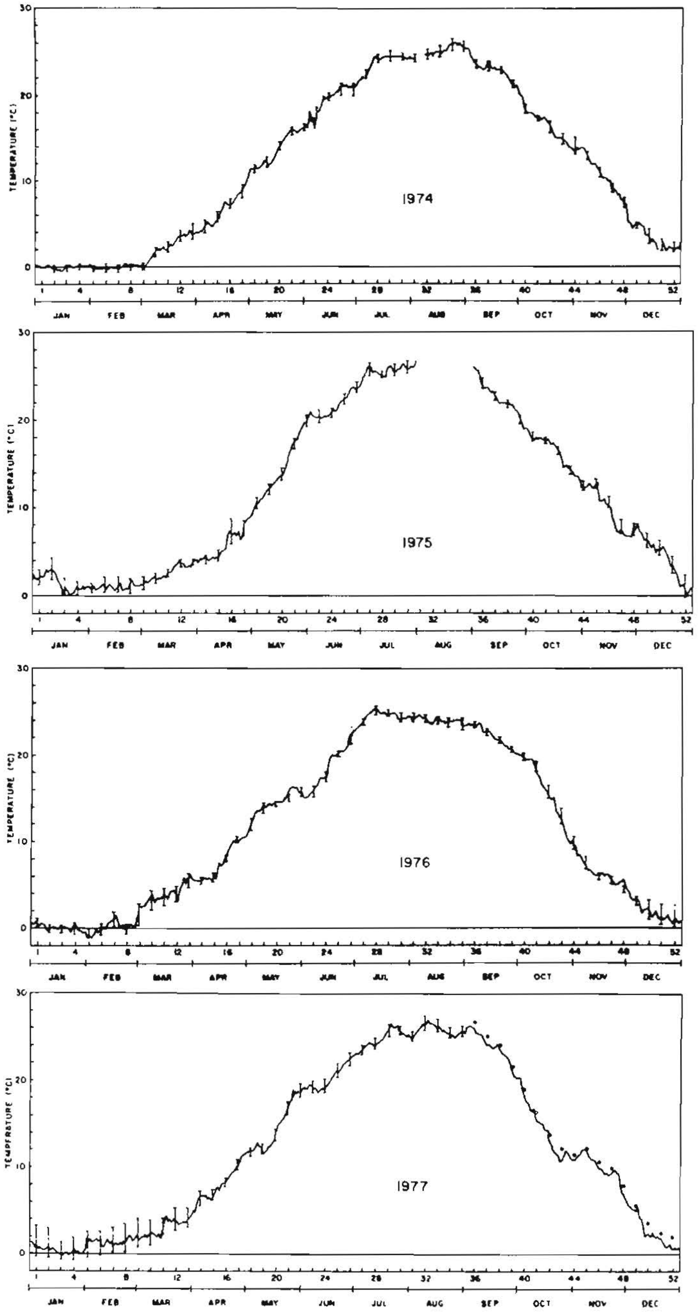

Figure 2. Seasonal variation of near-surface temperature of the Hudson River at Indian Point, 1974-77. The curves represent average daily temperatures; the ends of the bars correspond to weekly averages of the daily minimum and maximum temperatures. Data from Consolidated Edison of NY, Inc., 1978.

TABLE 2

Summary of times and temperatures when striped bass egss and larvae are found in the Hudson River off Indian Point

Life Stage	Times Present	Water Temperatures °C	Times of Peak Abundance	Water Temperatures °C
Eggs	Late April to Mid-June	10-20°	Early May to Late May	12-15°C
Yolk Sac Larvae	Late April to Mid-June	10-20°	Mid-May to Mid-June	14-20°C
Post Yolk Sac	Early May to Late July	10-25°	Early June to Early July	18-25°C

TABLE 3

Values for f for striped bass post yolk sac larvae acclimated to 16 or 18°C and exposed for 10 minutes to ΔTs ranging from 0 to 18°C. For each ΔT, 2 samples were passed through the NYU Condenser tube simulator at 1 m s^{-1}; 2 samples -- the controls -- were exposed only to ambient temperature and were not passed through the simulator. Each f is the mean of the 2 values obtained.

Acclimation Temperature(°C)	T(ΔT,°C)	Survivors(%)	Normalized Survivors(%)	Fractional Mortality, f
16.0	16.0(0.0)	14.3	24.6	0.75
16.0	23.0(7.0)	23.8	41.0	0.59
	NOTE:	Control survival was 58.0%		
18.0	18.0(0.0)	77.1	93.0	0.07
18.0	26.0(8.0)	57.0	68.8	0.31
18.0	28.0(10.0)	37.4	45.1	0.55
18.0	30.0(12.0)	29.2	35.2	0.65
18.0	32.0(14.0)	13.6	16.4	0.84
18.0	34.0(16.0)	12.9	15.6	0.84
18.0	36.0(18.0)	0.0	0.0	1.00
	NOTE:	Control survival was 82.9%		

TABLE 4

Values of f for striped bass post yolk sac larvae acclimated to 16.0 or 17.2°C and exposed for 10 minutes to ΔTs ranging from 0 to 18°C. For each ΔT, 2 samples passed through the NYU Condenser simulator at 3 m s^{-1}; 2 samples -- the controls -- were exposed only to ambient temperature and were not passed through the simulator. Each f is the mean of the 2 values obtained.

Acclimation Temperature(°C)	T(ΔT,°C)	Survivors(%)	Normalized Survivors(%)	Fractional Mortality, f
16.0	16.0(0.0)	42.1	72.5	0.28
16.0	23.0(7.0)	18.6	32.0	0.68
	NOTE:	Control survival was 58.0%		
17.2	17.2(0.0)	46.4	87.7	0.12
17.2	25.2(8.0)	37.9	71.6	0.28
17.2	27.2(10.0)	48.6	91.9	0.08
17.2	29.2(12.0)	14.7	27.8	0.72
17.2	31.2(14.0)	26.7	50.4	0.50
17.2	33.2(16.0)	9.9	18.7	0.81
17.2	35.2(18.0)	0.0	0.0	1.00
	NOTE:	Control survival was 52.9%		

TABLE 5

Values of f for striped bass post yolk sac larvae acclimated to 16.0 or 19.0°C and exposed to ΔTs from 0 to 7°C. For each ΔT, 2 samples were passed through the NYU condenser tube simulator at 2 m s^{-1}; 2 samples -- the controls -- were exposed only to ambient temperatures and were not passed through the simulator. Each f is the mean of the 2 values obtained.

Acclimation Temperature(°C)	T(ΔT,°C)	Survivors(%)	Normalized Survivors(%)	Fractional Mortality, f
16.0	16.0(0.0)	37.3	64.3	0.36
16.0	23.0(7.0)	62.4	107.5	0.00
	NOTE:	Control survival was 58.0%		
19.0	19.0(0.0)	85.8	92.1	0.08
19.0	24.0(5.0)	65.9	70.8	0.29
	NOTE:	Control survival was 93.1%		

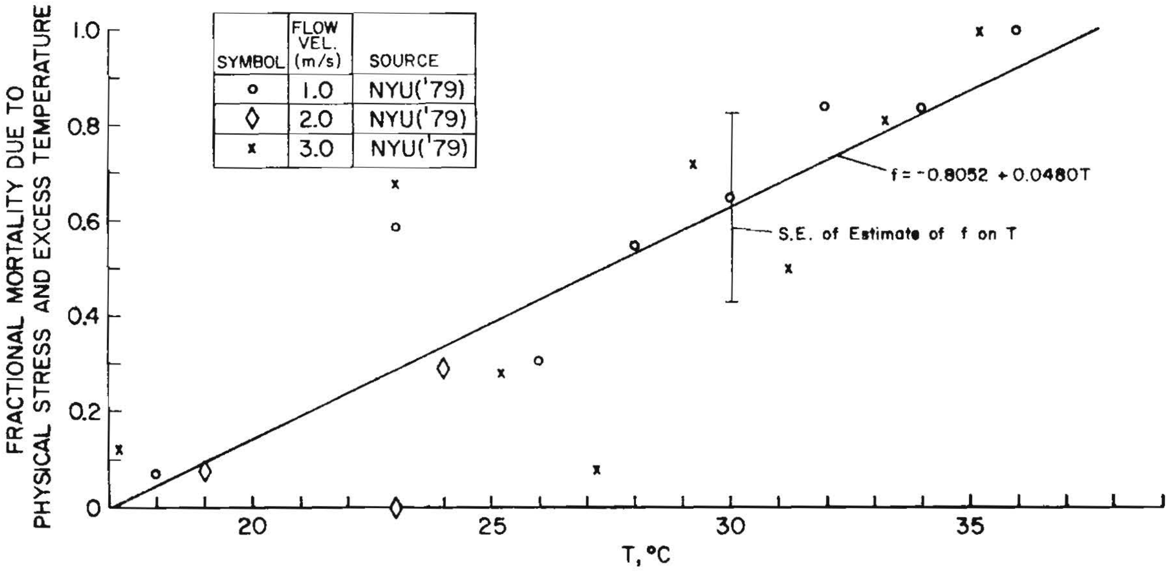

Figure 3. Fractional mortality of striped bass post yolk sac larvae caused by thermal and physical stresses experienced during passage through the condenser simulator at different temperatures (see Table 3-5).

For purposes of estimating f, the number of organisms killed by all stress to the total number of organisms entrained, as a function of temperature we shall use equation (7). Equation 7 indicates that the kill will be 100% (f = 1.00) at river temperatures ≥ 29.1°C.

D. Calculation of R/η versus T and ΔT

In Table 6 we have calculated for Indian Point Units 2 and 3, R/η -- the number of striped bass post yolk sac larvae killed per unit time per unit concentration in the river -- for a range of temperatures, 13 to 27°C, and a range of ΔTs, 8.5 to 24.5°C. Table 6 indicates that:

(1) The number of organisms killed per unit time per unit concentration (R/η) increases with river temperature for a given ΔT until f = 1.00 (river temperature + ΔT = 37.6°C);

(2) The rate of change of the entrainment mortality rate per unit concentration with ΔT, $\frac{\partial R/\eta}{\partial \Delta T}$, is < 0 for f ≤ 1 and all river temperatures > 15.77°C and > 0 for f ≤ 1 and river temperatures < 15.77°C. *Therefore, increasing ΔT by decreasing the flow rate will not be beneficial until river temperatures exceed ≈ 16°C or until f = 1.*

(3) An increase in ΔT to 16.5°C -- nearly a doubling -- would decrease the entrainment mortality rate per unit concentration (R/η) by 25% when river temperatures reach 23°C; at river temperatures ≥ 25°C it would reduce it by 36%.

Table 7 has also been calculated from equations (7) and (8) but with added mortality, independent of temperature and Q, to take into account pressure changes, shear forces, and abrasion in the circulating water pumps. Recent data (Coutant, personal communication) suggest that the mortality fraction for ichthyoplankton in pumps is 0.1. Since this fraction is independent of Q, halving Q by doubling the ΔT would reduce the entrainment mortality rate in the pumps to one-half. Table 7 shows that if one includes this additional mortality associated with passage through the pumps, the 25 and 36% reduction in R/η achieved by doubling ΔT is realized at 20 and 23°C instead of 23 and 25°C.

In summary, our analysis indicates that raising ΔT by reducing the flow of cooling water could decrease the pump entrainment mortality rate of striped bass ichthyoplankton at Indian Point when river temperatures exceed about 16°C. Since peak abundances of yolk sac and post yolk sac larvae occur at water temperatures of ≥ 15°C, these reductions in pump entrainment mortality could be important biologically. Our analysis also indicates that the model presented in Schubel and Marcy (1978) for reducing the entrainment mortality rate by increasing the ΔT is overly simplistic. The NYU condenser simulator data clearly show that the fractional entrainment mortality rates associated with each of the various kinds of stresses -- thermal, physical, and chemical -- are not independent as assumed in Schubel and Marcy (1978). They had little choice, however. There are not sufficient data to even begin to specify the functional relationships among these parameters.

A Note of Caution

These conclusions are based largely on a very small data set from NYU's condenser simulator studies; there are no other data we are aware of for this kind of analysis.

The fact that raising ΔT produces little advantage until river temperatures

TABLE 6

The number of entrained striped bass post yolk sac larvae killed per unit time per unit concentration, R/η, for different combinations of river temperatures and ΔT

River Temperature, °C

ΔT, °C	13	15	17	19	21	23	25	27	
8.5	24.90	35.43	45.97	56.51	67.05	77.59	88.12	98.66	
10.5	28.68	37.22	45.75	54.28	62.81	71.34	79.87	88.40	
12.5	31.26	38.43	45.59	52.76	59.92	67.09	74.26	74.64	25% Reduction
14.5	33.13	39.30	45.48	51.66	57.84	64.01	64.35	64.35	
16.5	34.54	39.97	45.40	50.83	56.25	56.55	56.55	56.55	
18.5	35.65	40.49	45.33	50.17	50.43	50.43	50.43	50.43	
20.5	36.54	40.91	45.28	45.51	45.51	45.51	45.51	45.51	50% Reduction
22.5	37.27	41.25	41.47	41.47	41.47	41.47	41.47	41.47	
24.5	37.89	38.08	38.08	38.08	38.08	38.08	38.08	38.08	
	May	May (late)	June (early)	June (late)	July (early)	July (late)	August (early)	August (late)	

TABLE 7

The number of entrained striped bass post yolk sac larvae killed per unit time per unit concentration, R/η, for different combinations of river temperatures and ΔT with added mortality of 10% due to passage through circulating water pumps.

River Temperature, °C

ΔT, °C	13	15	17	19	21	23	25	27	
8.5	35.87	46.41	56.95	67.49	78.02	88.56	99.10	109.64	
10.5	37.57	46.10	54.63	63.16	71.69	80.22	88.75	88.86	25% Reduction
12.5	38.73	45.89	53.06	60.22	67.39	74.55	74.64	74.64	
14.5	39.56	45.74	51.92	58.09	64.27	64.35	64.35	64.35	
16.5	40.19	45.62	51.05	56.48	56.55	56.55	56.55	56.55	50% Reduction
18.5	40.69	45.53	50.37	50.43	50.43	50.43	50.43	50.43	
20.5	41.09	45.46	45.51	45.51	45.51	45.51	45.51	45.51	
22.5	41.42	41.47	41.47	41.47	41.47	41.47	41.47	41.47	
24.5	38.08	38.08	38.08	38.08	38.08	38.08	38.08	38.08	
	May	May (late)	June (early)	June (late)	July (early)	July (late)	August (early)	August (late)	

exceed 16°C was unexpected. It is the result of the apparent synergism between thermal and physical streses contained in the condenser tube simulator data, Figure 3. Because of the great economic and environmental importance of making the "right" decisions for the Indian Point power plants, we strongly recommend that more data should be obtained on f using the NYU condenser simulator.

Finally, it should be emphasized that our study addressed only the question of whether pump entrainment mortalities at Indian Point Units 2 and 3 could be reduced by increasing the present ΔT of 8.5°C. It should not be interpreted as implying that ichthyoplankton mortalities which occur as a result of pump entrainment at present cooling water flows and ΔT do or do not produce biologically significant reductions in the recruit populations.

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APPENDIX

Original Data from NYU (1979)

Table 3-4. Survival of plume entrained and condenser tube passed *Morone saxatilis* (post yolk sac larvae) after a 10 minute exposure to elevated temperatures. Ambient temperature was 17.2°C. Flow rate was at 3.0 mps.

		% Survival							
Temperature,°C	(ΔT)	Plume entrained				Condenser Tube Passed			
		Immediate	(*)	24 hr.	48 hr.	Immediate	(*)	24 hr.	48 hr.
17.2	(0.0)	100.0	(52)	38.5	36.5	85.1	(47)	31.9	27.7
		100.0	(49)	67.3	59.2	100.0	(51)	60.8	51.0
25.2	(8.0)	100.0	(52)	82.7	76.9	100.0	(48)	31.3	25.0
		100.0	(53)	39.6	26.4	100.0	(54)	44.4	44.4
27.2	(10.0)	100.0	(51)	74.5	66.7	100.0	(52)	21.2	19.2
		100.0	(50)	98.0	82.0	100.0	(54)	75.9	70.4
29.2	(12.0)	100.0	(51)	49.0	45.1	100.0	(53)	18.9	13.2
		100.0	(50)	74.0	66.0	100.0	(57)	10.5	10.5
31.2	(14.0)	100.0	(52)	63.5	61.5	97.9	(47)	23.4	23.4
		100.0	(52)	61.5	57.7	94.0	(50)	30.0	30.0
32.2	(16.0)	96.1	(51)	21.6	13.7	92.5	(53)	5.7	3.8
		100.0	(52)	25.0	23.1	97.7	(43)	14.0	9.3
35.2	(18.0)	98.0	(50)	10.0	4.0	80.8	(26)	0.0	-
		98.1	(52)	5.8	3.8	90.2	(41)	0.0	-

Table 3-6. Survival of plume entrained and condenser tube passed *Morone saxatilis* (post yolk sac larvae) after a 10 minute exposure to elevated temperatures. Ambient temperature was 18.0°C. Flow rate was 1.0 mps.

		% Survival							
Temperature,°C	(ΔT)	Plume entrained				Condenser tube passed			
		Immediate	(*)	24 hr.	48 hr.	Immediate	(*)	24 hr.	48 hr.
18.0	(0.0)	100.0	(49)	77.8	65.3	100.0	(51)	90.2	82.4
		100.0	(50)	88.0	78.0	100.0	(50)	64.0	58.0
26.0	(8.0)	100.0	(50)	88.0	80.0	100.0	(50)	48.0	40.0
		100.0	(50)	84.0	76.0	97.6	(41)	65.9	63.4
28.0	(10.0)	100.0	(50)	82.0	70.0	96.1	(51)	39.2	31.4
		100.0	(50)	88.0	80.0	94.9	(59)	35.6	28.8
30.0	(12.0)	100.0	(51)	78.4	72.5	98.3	(60)	13.3	11.7
		100.0	(50)	74.0	68.0	100.0	(40)	45.0	37.5
32.0	(14.0)	100.0	(53)	64.2	52.8	100.0	(46)	15.2	15.2
		100.0	(52)	53.8	47.0	100.0	(42)	11.9	11.9
34.0	(16.0)	100.0	(52)	86.5	80.8	91.7	(60)	10.0	10.0
		100.0	(50)	60.0	54.0	96.5	(57)	15.8	10.5
36.0	(18.0)	100.0	(51)	4.1	4.1	92.5	(40)	0.0	-
		98.0	(50)	30.0	28.0	87.2	(47)	0.0	-

*Number exposed

Table 3-7. Survival of flow exposed and condenser tube passed (CTP) *Morone saxatilis* (yolk sac larvae) after a 10 minute exposure to varied flow velocities at ambient temperature (15.0°C) and at an elevated temperature (ΔT=7.0°C; 22.0 actual temperature). Plume exposed were subjected only to temperature variation.

		% Survival					
		CTP			Flow exposed		
Flow Rate	Temperature	Immediate	(*)	24 hr.	Immediate	(*)	24 hr.
1.0 mps	Ambient	100.0	(93)	4.3	91.8	(98)	17.3
		70.4	(71)	21.1	51.3	(117)	43.6
1.0 mps	ΔT	82.6	(86)	4.7	86.7	(98)	11.2
		55.7	(97)	49.5	42.9	(98)	22.4
2.0 mps	Ambient	83.3	(66)	24.2	41.9	(117)	18.8
		84.0	(81)	13.6	84.5	(97)	58.8
2.0 mps	ΔT	88.2	(93)	77.4	88.2	(110)	0.0
		40.4	(99)	1.0	85.1	(87)	0.0
3.0 mps	Ambient	67.8	(87)	35.6	73.2	(97)	44.3
		67.1	(85)	22.4	49.5	(95)	24.2
3.0 mps	ΔT	41.2	(97)	32.0	81.6	(98)	63.3
		57.0	(100)	12.0	73.5	(98)	59.2
Plume exposed	Ambient	98.0	(98)	4.1			
		99.0	(101)	1.0			
		61.3	(93)	50.5			
		80.0	(100)	71.0			
Plume exposed	ΔT	78.6	(98)	9.2			
		90.7	(97)	80.4			
		83.8	(99)	45.5			
		58.7	(92)	0.0			

*Number exposed

Tables 3-9. Survival of flow exposed and condenser tube passed (CTP) Morone saxatilis (post yolk sac larvae) after a 10 minute exposure to varied flow velocities at ambient temperature (16.0°C) and at an elevated temperature (ΔT=7.0°C; 23.0 actual temperature). Plume exposed were subjected only to temperature variation.

Flow Rate	Temperature	% Survival CTP Immediate	(*)	24 hr.	Flow exposed Immediate	(*)	24 hr.
1.0 mps	Ambient	96.9	(64)	20.3	97.9	(47)	14.9
		100.0	(49)	8.2	97.9	(47)	29.8
1.0 mps	ΔT	100.0	(29)	10.3	95.7	(47)	8.5
		97.7	(43)	37.2	96.2	(52)	42.3
2.0 mps	Ambient	100.0	(35)	57.1	100.0	(49)	49.0
		100.0	(40)	17.5	95.1	(41)	39.0
2.0 mps	ΔT	95.3	(43)	65.1	100.0	(46)	21.7
		100.0	(52)	59.6	100.0	(39)	61.5
3.0 mps	Ambient	97.6	(41)	34.1	100.0	(49)	32.7
		100.0	(46)	50.0	100.0	(42)	76.2
3.0 mps	ΔT	100.0	(40)	10.0	100.0	(51)	41.2
		95.8	(48)	27.1	100.0	(50)	34.0
Plume exposed	Ambient	100.0	(49)	49.0			
		100.0	(48)	75.0			
		100.0	(50)	50.0			
Plume exposed	ΔT	100.0	(50)	32.0			
		100.0	(48)	62.5			
		100.0	(50)	54.0			

*Number exposed